



ULTRACAM

Calibration Report



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Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil

www.hiparc.com

UltraCam Lp, GSD25 cm, RGB



ULTRACAM

Geometric Calibration

Camera: UltraCam Eagle Prime
Serial: UC-Ep-1-70910052-f210

Panchromatic Camera: ck = 212.100 mm
Multispectral Camera: ck = 212.100 mm

PPA Information: X: 0.000 mm
Y: -0.184 mm



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	68.034mm	14790pixel
	cross track	105.846mm	23010pixel
Image Extent		(-34.017, -52.923)mm	(34.017, 52.923)mm
Pixel Size		4.600µm*4.600µm	
Focal Length	ck	212.100mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	-0.184mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

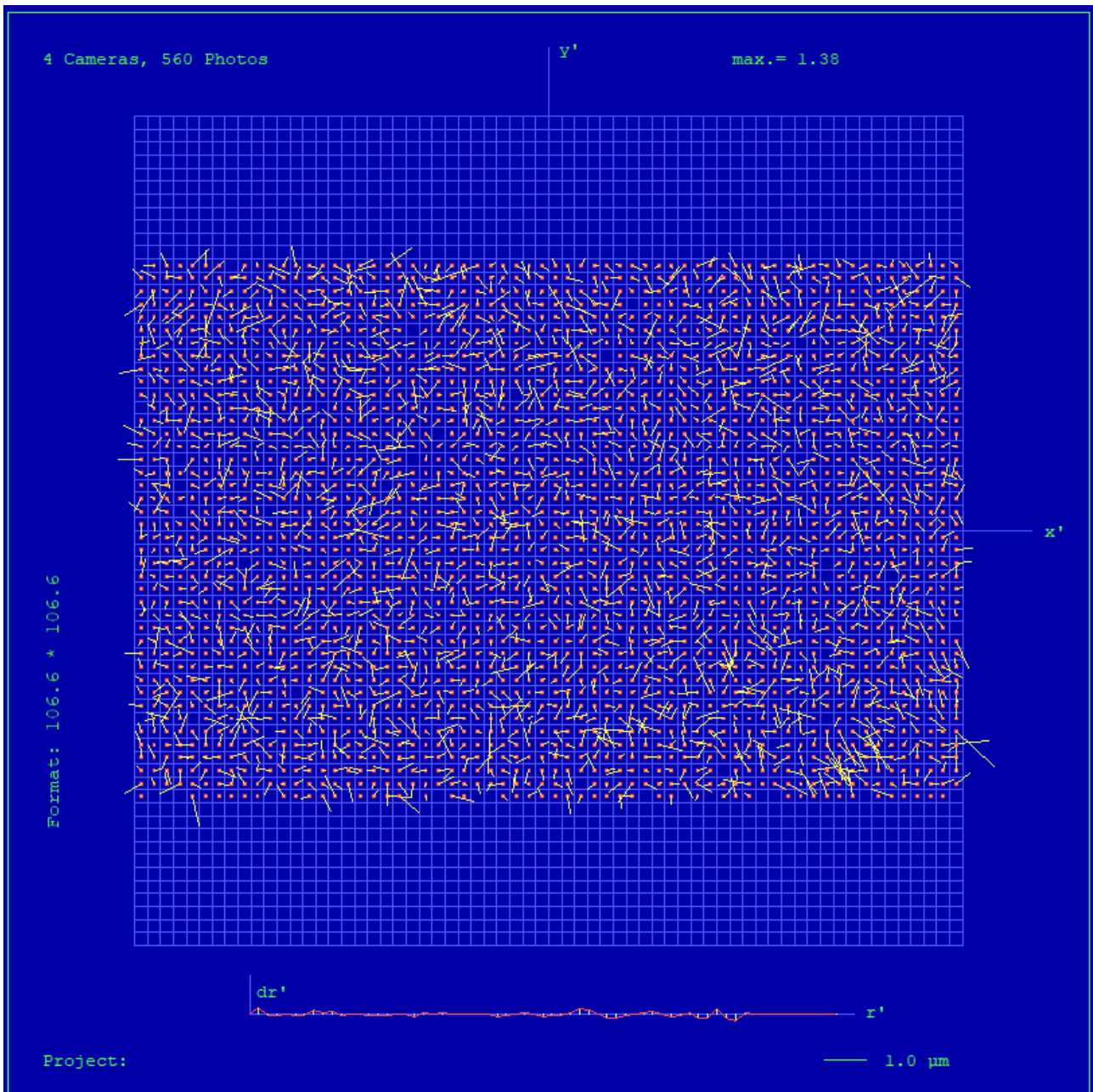
Multispectral Camera

Medium Format Multispectral Output Image (Upscaled to panchromatic image format)

Image Format	long track	68.034mm	4930pixel
	cross track	105.846mm	7670pixel
Image Extent		(-34.017, -52.923)mm	(34.017, 52.923)mm
Pixel Size		13.800µm*13.800µm	
Focal Length	ck	212.100mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	-0.184mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



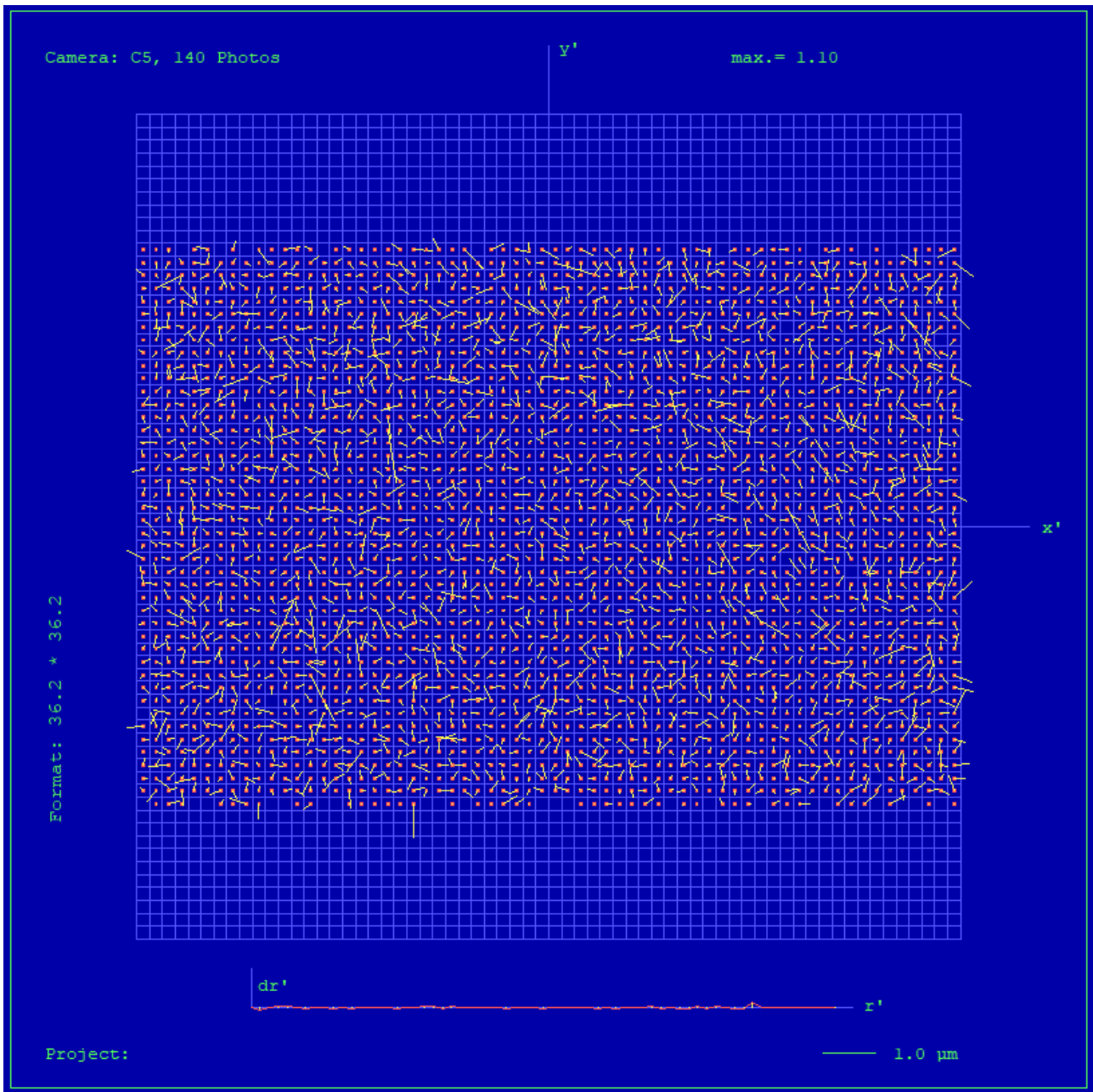
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.54 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): 0.42 μm



Explanations

Calibration Method:

The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

Number of point measurements for the panchromatic camera : >16000

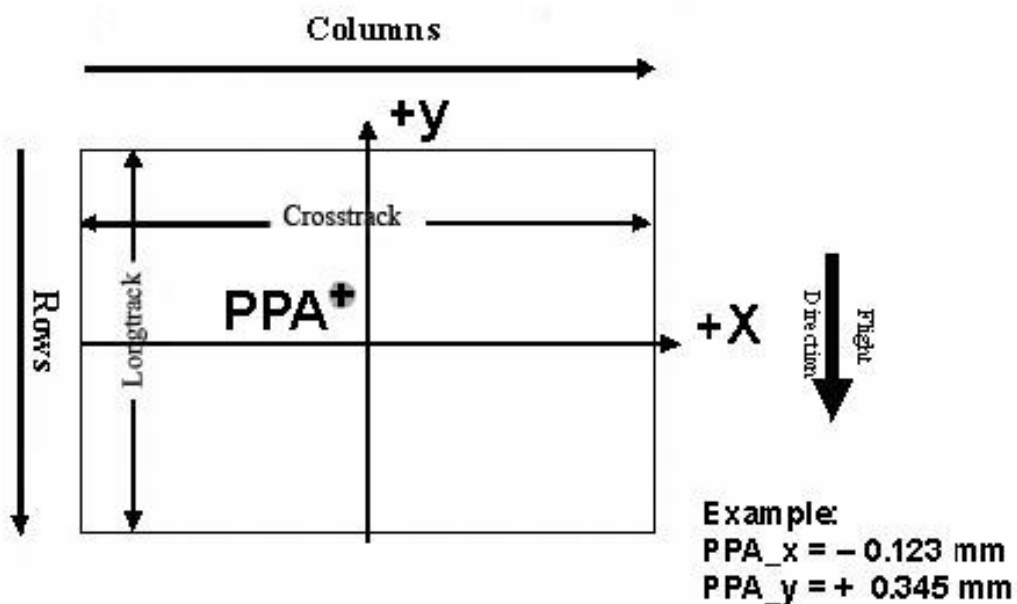
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

Level 2 Image Coordinate System:

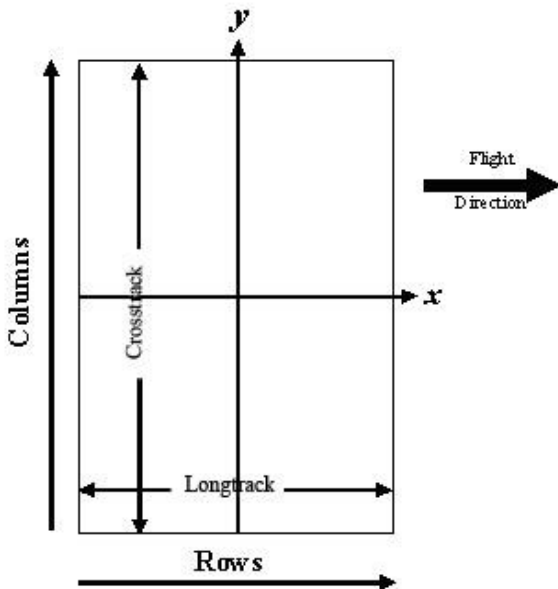
Lvl2, Camera prop. Orientation



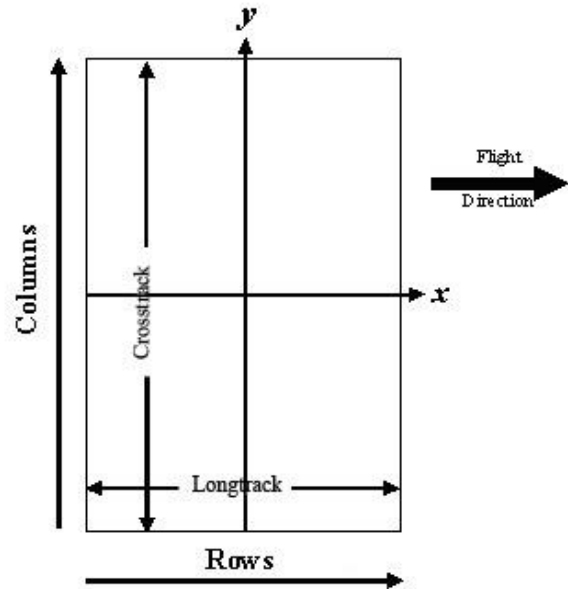
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



Level 3 Image Coordinate System:
(after rotation of 270° CW)



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

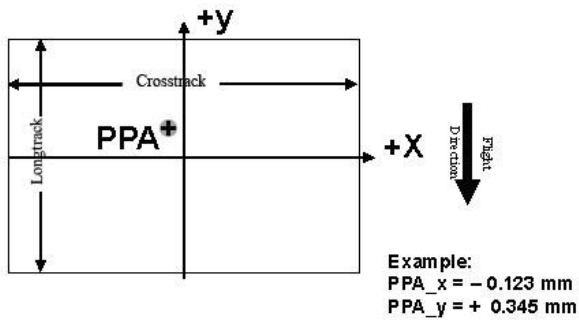
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified for clockwise (CW) rotation in steps of 90 degrees, according to the principal point coordinate given on page 4 for high- and low resolution images.

Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	-0.184
Level 3	0	0.000	-0.184
Level 3	90	-0.184	0.000
Level 3	180	0.000	0.184
Level 3	270	0.184	0.000

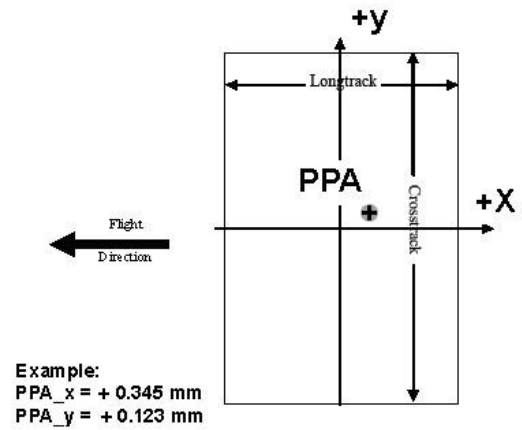


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

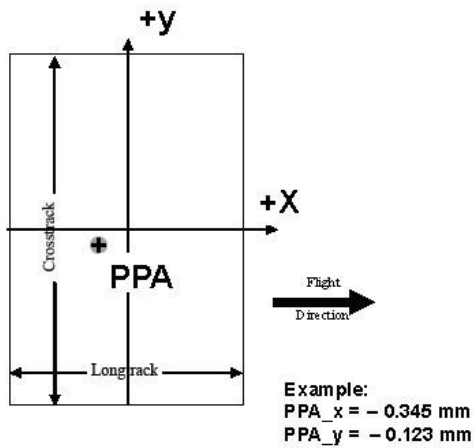
Lvl3, Rotation 0 deg clockwise



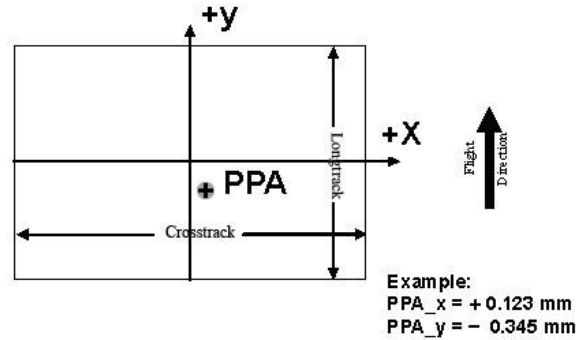
Lvl3, Rotation 90 deg clockwise



Lvl3, Rotation 270 deg clockwise



Lvl3, Rotation 180 deg clockwise





Lens Resolving Power

The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.

Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

The curves are given for the meridional (tangential) and sagittal (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

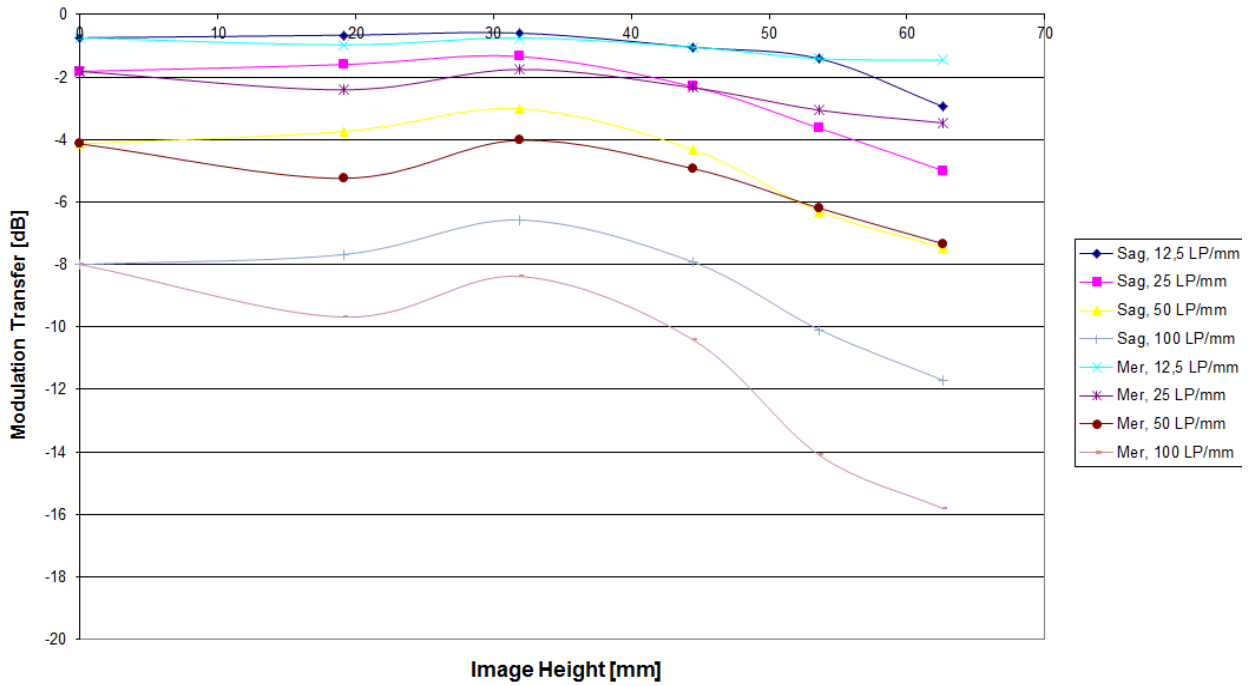
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

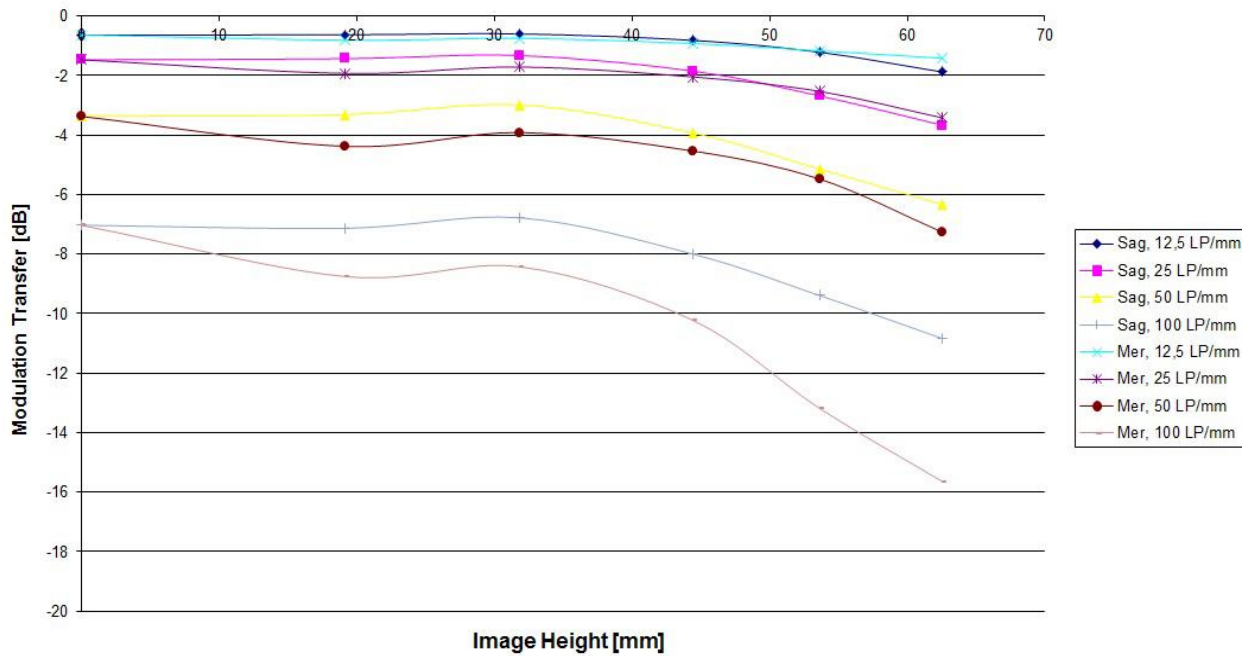
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:8,6/210mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:8,6/210mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:8,6/210mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:8,6/210mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic Vexcel HR Digaron 1:5.6/70mm, Qioptic GmbH, Germany
C5 (GREEN)	Qioptic Vexcel HR Digaron 1:5.6/70mm, Qioptic GmbH, Germany
C6 (BLUE)	Qioptic Vexcel HR Digaron 1:5.6/70mm, Qioptic GmbH, Germany
C7 (NIR)	Qioptic Vexcel HR Digaron 1:5.6/70mm, Qioptic GmbH, Germany



Modulation versus Image Height - Aperture f/ 5.6

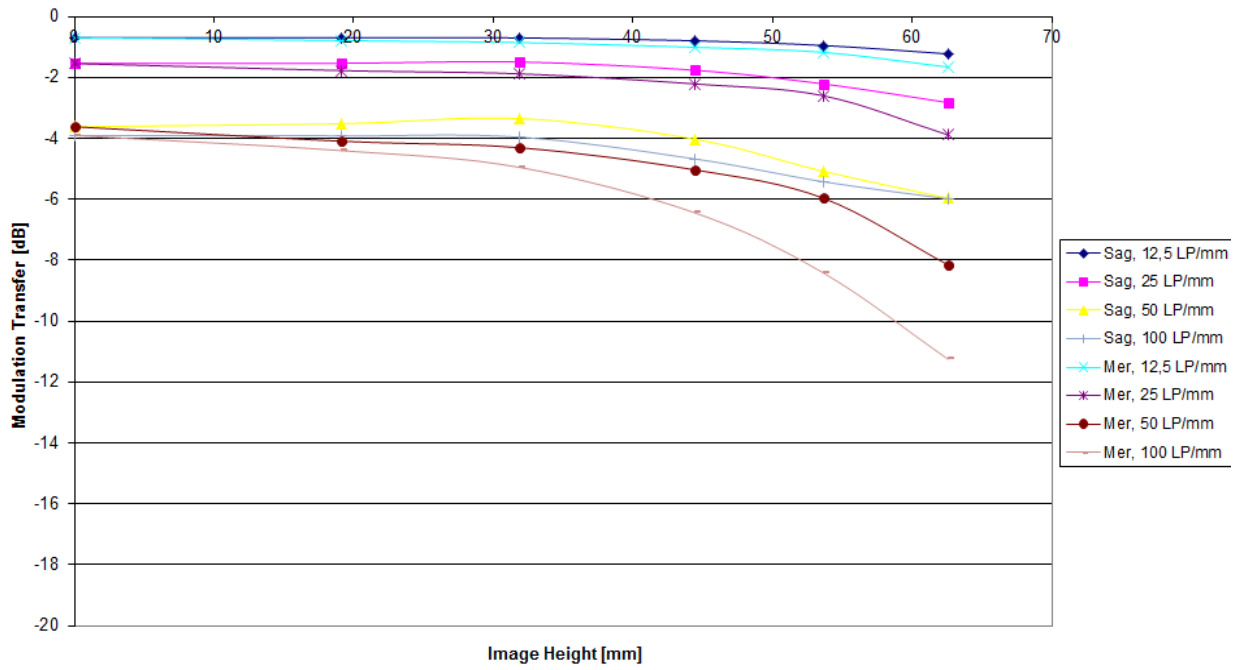


Modulation versus Image Height - Aperture f/ 6.7

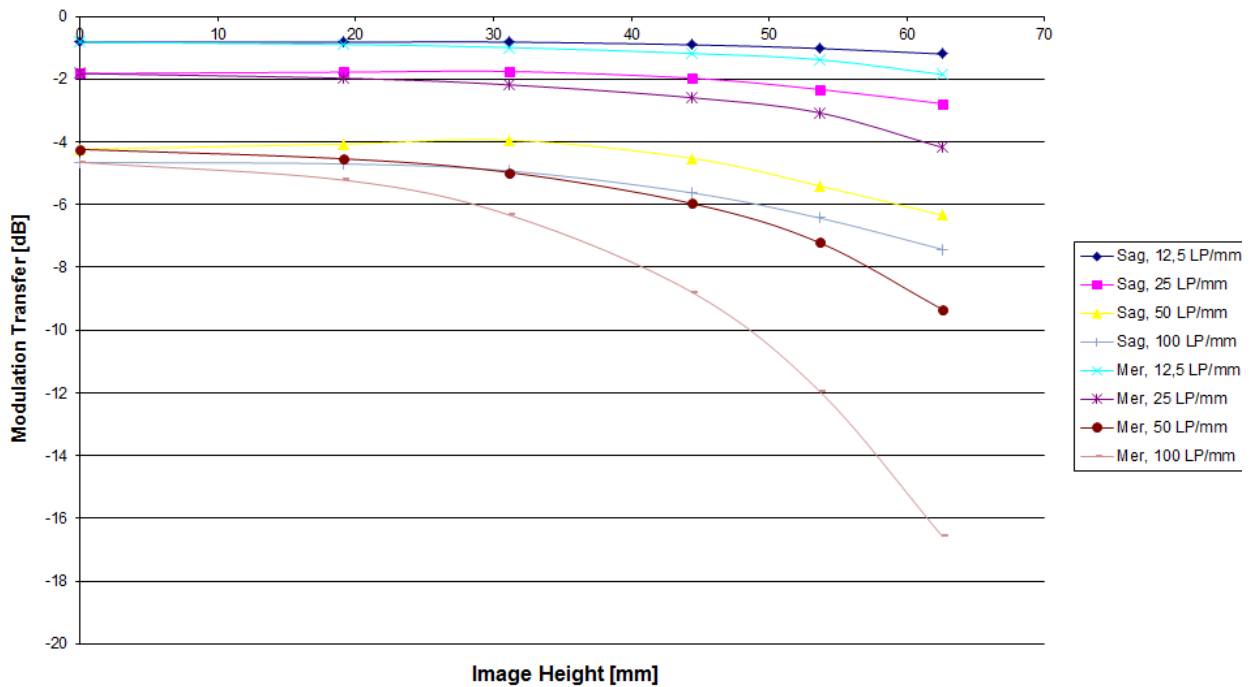




Modulation versus Image Height - Aperture f / 8

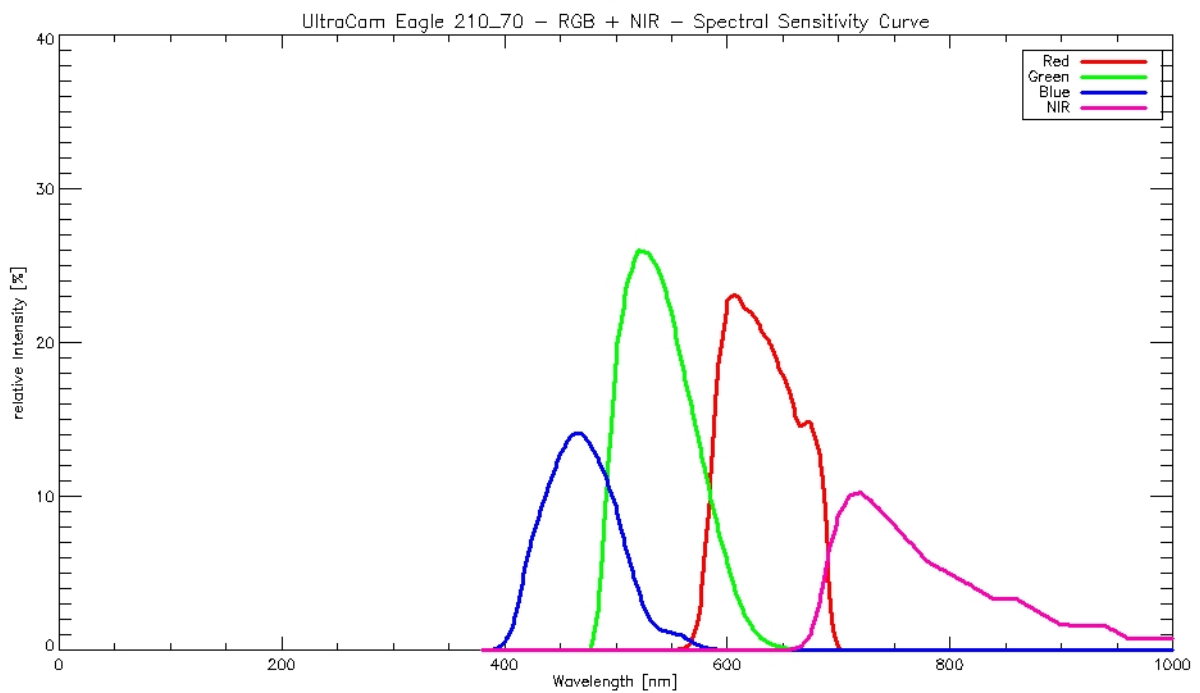
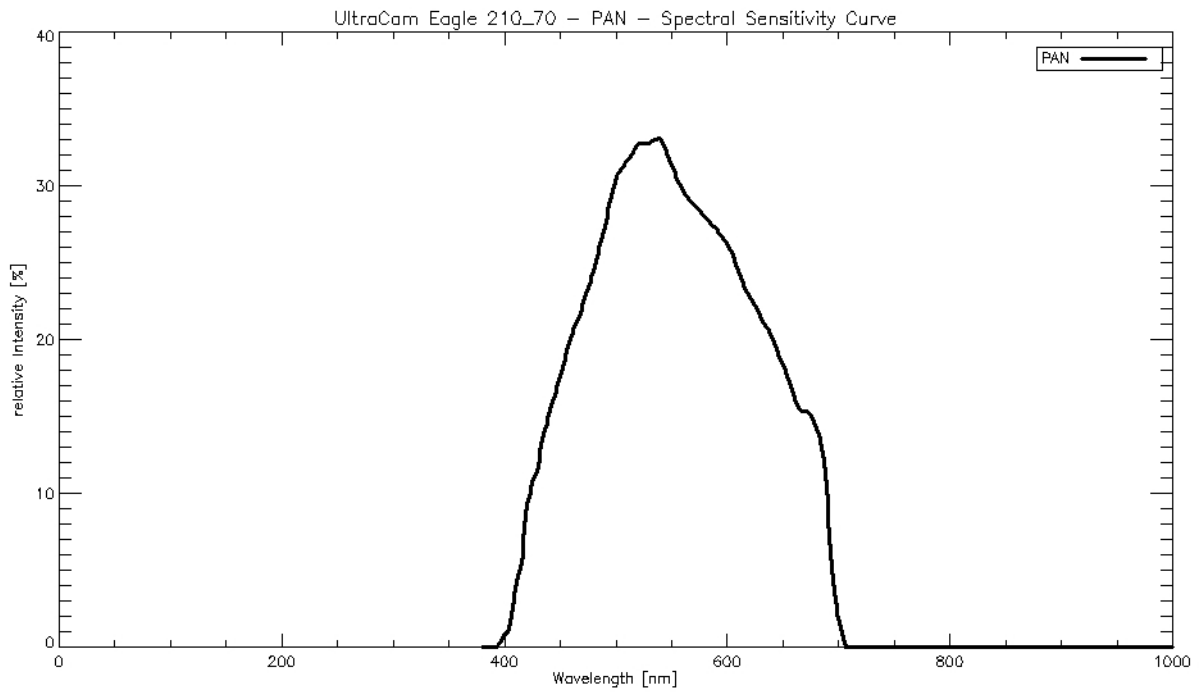


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





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Radiometric Calibration

Camera: UltraCam Eagle Prime
Serial: UC-Ep-1-70910052-f210

	PAN	R, G, NIR	B
Used Apertures	F7.8	F5.6	F5.6
	F9.5	F6.7	F5.6
	F11	F8	F5.6
	F13	F9.5	F6.7
	F16	F11	F8
	F22	F16	F11

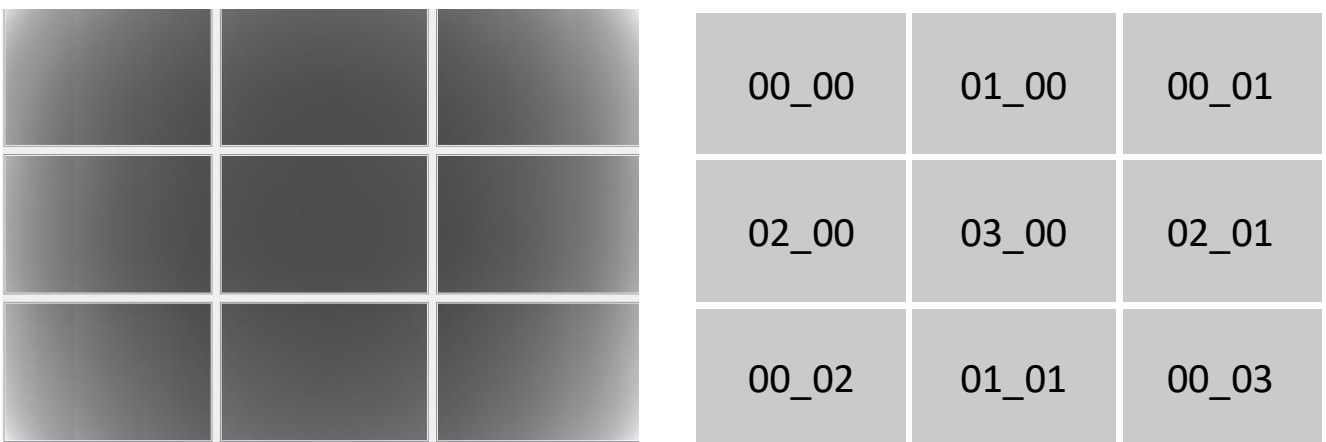
Dead Pixel Report: see Appendix I



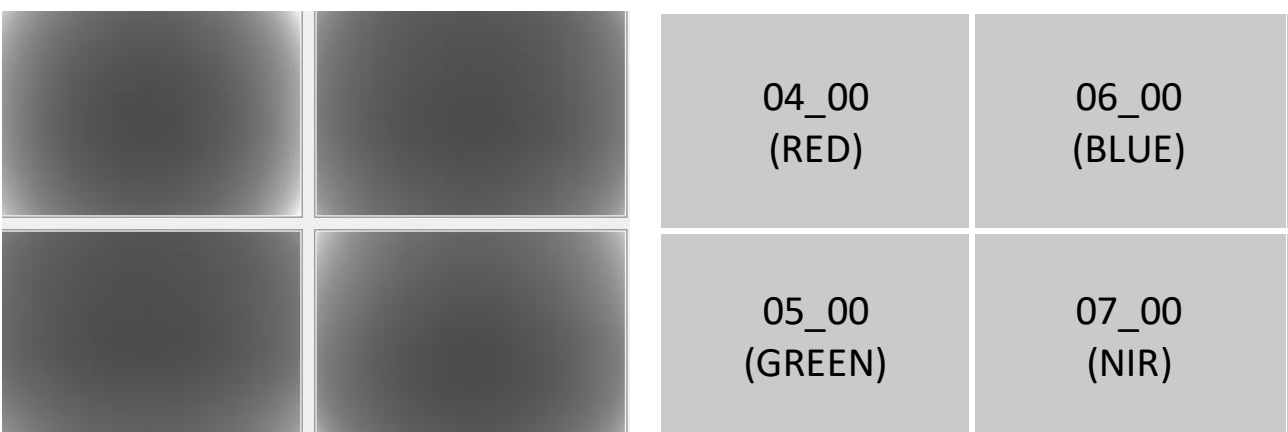
Calibration of Vignetting for working Aperture F8

	PAN	R, G, NIR	B
Aperture	F7.8	F5.6	F5.6

Graphical Overview of Pan Sensors:



Graphical Overview of Multispectral Sensors:





Explanations

Calibration Method:

The radiometric calibration is based on a series of 50 flat field images for each aperture size and sensor. The flat field is illuminated by eight normal light lamps with known spectral illumination curves.

These images are used to calculate the specific sensitivity of each pixel to compensate local as well as global variations in sensitivity. Sensitivity tables are calculated for each sensor and aperture setting, and applied during post processing from level 0 to level 1.

Outlier Pixels that do not have a linear behavior as described in the CCD specifications are marked as defective during the calibration procedure. These pixels are not used or only partially used during post processing and the information is restored by interpolation between the neighborhood pixels surrounding the defective pixels.

Certain pixels that are named Qmax pixels due to the fact that they can only store and transfer charge up to a certain maximum amount are detected in an additional calibration step. These pixels are treated differently during post processing, since their behavior can affect not only single pixel values but whole columns.



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Shutter Calibration

Camera: UltraCam Eagle Prime
Serial: UC-Ep-1-70910052-f210

Panchromatic Camera: 4 * Prontor Magnetic 0 HS
Prontor-Werk Alfred Gauthier GmbH, Germany

Multispectral Camera: 4 * Prontor Magnetic 0 HS
Prontor-Werk Alfred Gauthier GmbH, Germany



Calibration of Shutter Release Times:

The shutter release times measured during the calibration describe the time from the moment when the electrical current through the shutter is turned off by the electronics, until the shutter is mechanically closed.

This time is relevant for the exposure control and needs to be known before image recording can take place.

Currently used SRT values (operation values):

Cone Number	Lens Serial Number	SRT F8 [ms]	SRT F9.5 [ms]	SRT F11 [ms]	SRT F13 [ms]	SRT F16 [ms]	SRT F22 [ms]	Measurement Tolerance [ms]
C0 (Pan)	12 19 18 82	5.36	5.58	6.01	6.43	6.74	7.07	+/- 0.2
C1 (Pan)	12 17 56 28	5.46	5.67	6.04	6.48	6.80	7.11	+/- 0.2
C2 (Pan)	12 19 18 88	5.09	5.28	5.71	6.04	6.34	6.71	+/- 0.2
C3 (Pan)	12 19 18 77	5.72	5.87	6.32	6.62	6.99	7.37	+/- 0.2
C4 (Red)	12 17 36 38	7.39	7.45	7.70	7.82	8.12	8.49	+/- 0.2
C5 (Green)	12 17 36 47	6.91	7.11	7.30	7.53	7.58	7.95	+/- 0.2
C6 (Blue)	12 17 36 36	7.34	7.39	7.39	7.49	7.77	8.00	+/- 0.2
C7 (NIR)	12 17 36 40	6.61	6.78	7.04	7.27	7.51	7.59	+/- 0.2



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Electronics and Sensor Calibration

Camera: UltraCam Eagle Prime
Serial: UC-Ep-1-70910052-f210

Panchromatic Camera: 9 * FTF7852-M Area CCD Sensor by DALSA
Multispectral Camera: 4 * FTF7852-M Area CCD Sensor by DALSA



Calibration of Negative Substrate Voltage (VNS):

For optimum performance of the DALSA CCD sensors, the negative substrate voltage is adjusted to a value specified by DALSA.

This voltage value is measured to achieve the best anti-blooming performance possible for each particular sensor.

Currently used VNS and VOG values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	VNS Voltage [V]	VOG Voltage [V]
00_00	FTF7852-M	17 36 82/078	27.20	5.11
00_01	FTF7852-M	17 36 82/046	27.00	4.98
00_02	FTF7852-M	17 36 82/019	27.00	5.03
00_03	FTF7852-M	17 36 82/048	27.20	5.03
01_00	FTF7852-M	17 36 82/014	26.80	5.07
01_01	FTF7852-M	17 36 82/052	27.40	4.77
02_00	FTF7852-M	17 36 82/009	26.60	4.93
02_01	FTF7852-M	17 36 82/032	26.60	5.04
03_00	FTF7852-M	17 36 82/049	27.20	4.80
04_00 (red)	FTF7852-M	17 36 82/044	27.00	5.22
05_00 (green)	FTF7852-M	17 36 82/067	27.20	5.13
06_00 (blue)	FTF7852-M	17 36 82/049	27.00	5.17
07_00 (NIR)	FTF7852-M	17 36 82/026	26.60	5.00



Calibration of Intensity Threshold for Exposure Control:

Each CCD sensor and electronics module varies slightly in global sensitivity and intensity scale.

Therefore the maximum possible intensity of each sensor needs to be measured to evaluate the sensitivity behavior of the CCD and electronics.

This value is used as a threshold for the exposure control dialogue shown in the in-flight user interface of the Eagle.

Currently used Threshold values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]	
			Normal	Turbo
00_00	FTF7852-M	17 36 82/078	12630	11550
00_01	FTF7852-M	17 36 82/046	12620	11450
00_02	FTF7852-M	17 36 82/019	12020	11070
00_03	FTF7852-M	17 36 82/048	12210	11220
01_00	FTF7852-M	17 36 82/014	12030	11070
01_01	FTF7852-M	17 36 82/052	11810	10930
02_00	FTF7852-M	17 36 82/009	12490	11360
02_01	FTF7852-M	17 36 82/032	12310	11250
03_00	FTF7852-M	17 36 82/049	12180	11180
04_00 (red)	FTF7852-M	17 36 82/044	12390	11260
05_00 (green)	FTF7852-M	17 36 82/067	12440	11200
06_00 (blue)	FTF7852-M	17 36 82/049	12810	11680
07_00 (NIR)	FTF7852-M	17 36 82/026	12390	11300



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Summary

Camera: UltraCam Eagle Prime
Serial: UC-Ep-1-70910052-f210

Laboratory Calibration Date: Feb-01-2022
Camera Revision: Rev02.00

Date of Report: Feb-09-2022
Version of Report: V01

The following calibrations have been performed for the above mentioned digital aerial mapping camera:

- Geometric Calibration
- Radiometric Calibration
- Shutter Calibration
- Sensor and Electronics Calibration

This equipment is operating fully within specification as defined by Vexcel Imaging GmbH.

Dr. Michael Gruber
Chief Scientist, Photogrammetry
Vexcel Imaging GmbH

Dipl. Ing. (FH) Helmut Jauk
Senior Project Engineer R&D
Vexcel Imaging GmbH



Appendix I

Dead Pixel Report:

Sensor number		
Anomaly type	X-Coordinate	Y-Coordinate

C00-00

PIXEL: 4962/ 562
PIXEL: 1770/ 704
PIXEL: 2895/1188
PIXEL: 3081/1782
PIXEL: 5029/2243
PIXEL: 977/2377
PIXEL: 6257/4533
PIXEL: 4305/4631

C00-01

PIXEL: 2289/ 22
PIXEL: 7011/ 177
PIXEL: 7283/ 437
PIXEL: 3011/ 865
PIXEL: 1878/ 964
PIXEL: 3578/1495
PIXEL: 4026/1848
PIXEL: 989/2092
PIXEL: 6841/2267
PIXEL: 3619/2561
PIXEL: 7628/2648
PIXEL: 2244/2816
PIXEL: 4420/2869
PIXEL: 1414/3251
PIXEL: 7216/3360
PIXEL: 5773/4459
PIXEL: 3665/1128
PIXEL: 3666/1128
PIXEL: 5851/3012
PIXEL: 5852/3012
PIXEL: 3868/3371
PIXEL: 3868/3370



C00-02

PIXEL: 2147/ 210
PIXEL: 2003/ 907
PIXEL: 1998/1021
PIXEL: 493/1629
PIXEL: 2759/2299
PIXEL: 4269/2810
PIXEL: 5216/3027
PIXEL: 6405/3059
PIXEL: 906/3142
PIXEL: 6599/3493
PIXEL: 7285/4001
PIXEL: 3509/4488

C00-03

PIXEL: 4060/ 528
PIXEL: 683/1307
PIXEL: 4118/1317
PIXEL: 1146/1639
PIXEL: 3017/3069
PIXEL: 7392/3107
PIXEL: 1057/3179
PIXEL: 1044/3184
PIXEL: 1047/3185
PIXEL: 1048/3185
PIXEL: 4335/4057
PIXEL: 5762/4207
PIXEL: 3385/4244
PIXEL: 4850/ 143
PIXEL: 3287/4350
PIXEL: 3286/4350
PIXEL: 4849/ 143
PIXEL: 4850/ 144
PIXEL: 4851/ 143

C01-00

PIXEL: 801/ 281
PIXEL: 7116/1871
PIXEL: 1137/2258
PIXEL: 6248/2302
PIXEL: 89/4637



C01-01

PIXEL: 6522/ 243
PIXEL: 874/ 876
PIXEL: 4430/4775
PIXEL: 6361/4967
PIXEL: 930/5120
PIXEL: 160/4955
PIXEL: 160/4956
PIXEL: 159/4954

C02-00

PIXEL: 1125/ 153
PIXEL: 5455/ 431
PIXEL: 764/ 492
PIXEL: 1017/ 911
PIXEL: 2722/1045
PIXEL: 915/1588
PIXEL: 632/2692
PIXEL: 1295/2901
PIXEL: 4311/3116
PIXEL: 6049/3263
PIXEL: 2882/3341
PIXEL: 2935/4732
PIXEL: 139/1698
PIXEL: 140/1698
PIXEL: 6878/1818
PIXEL: 7318/4085
PIXEL: 138/1698

C02-01

PIXEL: 6270/ 359
PIXEL: 5220/1155
PIXEL: 2160/1282
PIXEL: 3176/2567
PIXEL: 2136/2893
PIXEL: 7028/4872
PIXEL: 569/4446
PIXEL: 570/4446
PIXEL: 569/4447
PIXEL: 570/4447

C03-00

PIXEL: 6115/ 266
PIXEL: 4401/ 546
PIXEL: 3501/4984
PIXEL: 1038/5021
PIXEL: 519/5165
PIXEL: 518/5165



C04-00

PIXEL: 5507/ 139
PIXEL: 5831/1700
PIXEL: 3599/3086
PIXEL: 839/3839
PIXEL: 5942/4636
PIXEL: 3024/4865
PIXEL: 973/4697

C05-00

PIXEL: 5595/ 27
PIXEL: 3072/ 900
PIXEL: 3550/1303
PIXEL: 6632/1341
PIXEL: 2219/1473
PIXEL: 4928/1759
PIXEL: 791/2342
PIXEL: 5677/3031
PIXEL: 6212/4243
PIXEL: 4474/4933
PIXEL: 6687/5161
PIXEL: 5078/ 564
PIXEL: 5079/ 564
PIXEL: 5079/ 563

C06-00

PIXEL: 5931/1251
PIXEL: 2300/4041
PIXEL: 1513/4273
PIXEL: 212/4283
PIXEL: 213/4283
PIXEL: 448/2273
PIXEL: 4923/2507
PIXEL: 4924/2507
PIXEL: 4923/2506
PIXEL: 4924/2506

C07-00

PIXEL: 4207/ 116
PIXEL: 313/1102
PIXEL: 4473/2170
PIXEL: 4678/4855
PIXEL: 7169/4987
PIXEL: 4375/5070
PIXEL: 393/ 262
PIXEL: 393/ 263
PIXEL: 394/ 263



Notes

COLUMN anomaly: all pixels below the Qmax detector at location (X,Y) may be affected.

PIXEL anomaly: single detector at location (X,Y) is not functioning within normal range

The Level0 coordinates exclude the two leftmost pixels containing the line index: the corresponding pixel can therefore be located at column (X+2,Y).



Appendix II

Calibration and Modification Dates

Type of Calibration	Laboratory Calibration Date	Modification Date	Modification Reason
Geometric Calibration	01.Feb.2022	01.Feb.2022	
Radiometric Calibration	01.Feb.2022	01.Feb.2022	
Shutter Calibration	01.Feb.2022	01.Feb.2022	
Electronics and Sensor Calibration	01.Feb.2022	01.Feb.2022	

Note: The above-mentioned Laboratory Calibration Dates represent the dates the camera was calibrated in one of our calibration labs for a full Laboratory Calibration. The Modification date represents a date on which the calibration has been modified due to a calibration enhancement or part exchange. It is an additional information and does not replace the Laboratory Calibration date in any way. With the Modification Reason, always the last modification to the calibration is highlighted.